

**CONSTRAINTS ON SOLAR WIND PLASMA PROPERTIES
DERIVED FROM COORDINATED CORONAL OBSERVATIONS**

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Final Report

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Final Report on the grant NAG5-9564 "Constraints on Solar Wind Plasma Properties Derived from Coordinated Coronal Observations"

1.1 Scope of the Investigation

The goal of the proposed research was to increase the understanding of coronal plasma phenomena by making use of different observational approaches and combine the observations with the necessary theoretical considerations.

1.2 Progress Made During the Funding Period

We studied the formation of spectral lines in the corona and transition region. The focus was on spectral lines commonly used as density and temperature diagnostic, mainly the lines Mg IX λ 706 and 749, and Si VIII λ 1440 and 1445 which were observed by SUMER in polar coronal hole and other coronal regions. We investigated these spectral lines for density and temperature dependence and found that the Mg lines are indeed a good temperature diagnostic, basically independent of density.

We compared the spectral line ratios that would arise from the type of temperature profile commonly used to explain in situ ion fractions with the actual observed line ratios (see Figure 1, solid lines). Also shown in this figure are the observed values of the ratios from Wilhelm et al. (1998, dotted lines). It is quite obvious from this figure that the type of temperature profiles derived from the charge state measurements results not only in the wrong values of the line ratios, but also the gradients of these curves are completely different. This study shows, in agreement with our previous studies, that there is a significant discrepancy between in situ ion fractions and observed coronal electron temperatures.

We also carried out a theoretical study to investigate how large the electron temperatures can be in the near sun region. We find that if in situ observations of mass flux and electron temperatures are taken into account, then the high electron temperatures necessary to explain in situ ion fractions cannot be achieved in the corona even from a purely theoretical point of view without violating constraints on mass flux and in situ electron temperature (e.g. Esser et al. 2002).

We carried out more detailed studies to show that differential flow speeds between ions of the same element can not bridge the above gap between low coronal electron temperatures and high in situ ion fractions. (Chen, Esser and Hu 2002a; Chen Esser and Hu 2002b). Even though differential flow speeds between ions of the same element in the fast solar wind do develop beyond a certain heliocentric distance (see Figure 2 below), this is beyond the region where a substantial fraction of minor ions form, and differential flow speeds with a low electron temperature in the coronal hole cannot account for the observed high ion charge states.

To investigate the drift between core and halo in the electron distribution function, which is observed in situ in the solar wind, we developed the first solar wind model with two electron populations. It was found that the anomalous frictional forces acting on the halo electrons are the dominant factor inhibiting the core-halo drift in the fast solar wind.

We used kinetic modeling to investigate the Alfvénic turbulence in the extended corona. In these studies we also included the effects of proton heating.

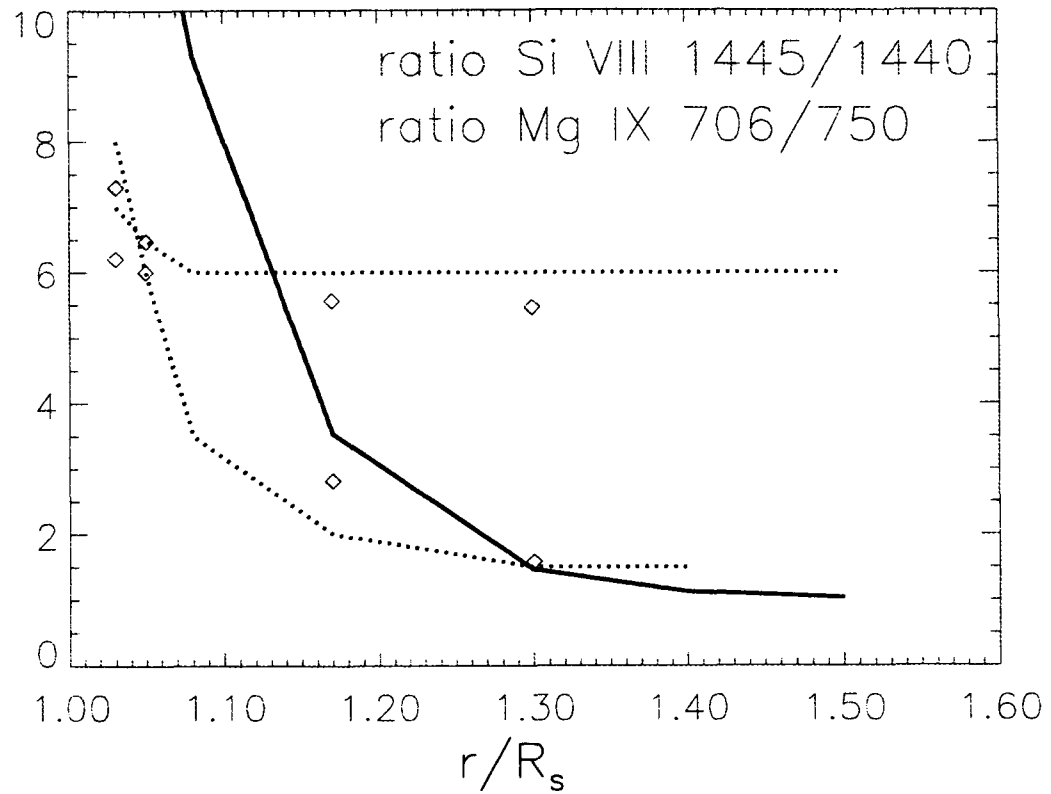


Fig. 1. Mg and Si line ratios from a typical electron temperature derived from in situ ion fractions (solid lines), line ratios observed by SUMER (Wilhelm et al. 1998, dotted lines). As a comparison we also show the line ratios calculated from the temperatures and density derived from these SUMER observations, but using a different set of atomic data (CHIANTI) instead of the atomic data used in the Wilhelm et al. (1998) paper (squares). The figure shows that the electron temperatures commonly derived from in situ ion charge states do not fit the line ratios observed in the corona.

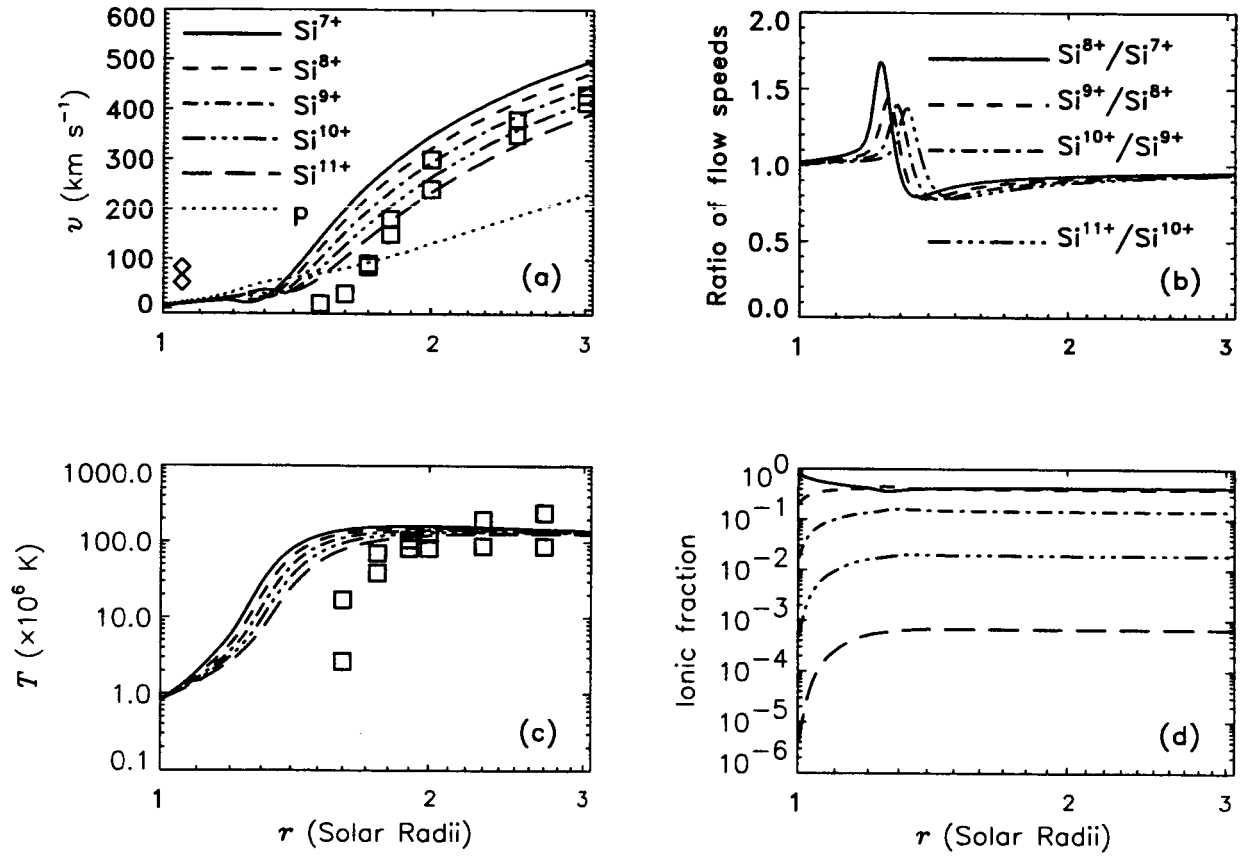


Fig. 2. Solutions for 5 adjacent Si ions and protons. The UVCS observations of O^{5+} are shown as a comparison (squares). At the distance where the charge states form, below 1.5 solar radii, the differential flow speeds are small.

2. Papers fully or partially funded by the grant

R. Esser and R. J. Edgar, Differential flow speeds of ions of the same element: Effects on solar wind ion fractions, *Astrophys. J.*, **563**, 1055, 2001.

R. Esser and R. J. Edgar, Constraints on ion outflow speeds and electron distribution function in the corona derived from SUMER electron temperatures and SWICS ion fractions, *Adv. Space Res.*, **30**, 481, 2002.

G. Poletto, S. T. Suess, D. A. Biesecker, R. Esser, G. Gloeckler, Y.-K. Ko and T. H. Zurbuchen, Low-latitude solar wind during the Fall 1998 SOHO-Ulysses quadrature, *J. Geophys. Res.*, **107**, 1300, 2002.

Y. Chen, R. Esser and Y.-Q. Hu, A theoretical model for O(+5) (O(+7)) ions in the fast solar wind, *J. Geophys. Res.*, **107**, A11, SSH 11-1, 2002.

Y. Chen, R. Esser and Y.-Q. Hu, Formation of minor-ion charge states in the fast solar wind: Roles of differential flow speeds of ions of the same element, *Astrophys. J.*, **582**, 467, 2003.

Y. Chen, R. Esser and Y. Q. Hu, Numerical modeling of the halo electrons in the fast solar wind, *J. Geophys. Res.*, **108**, 1371, 2003.

R. Esser, Streamers and the fast solar wind - preface, *Advances in Space Res.*, accepted, 2003.

S. R., Cranmer, and A. A., van Ballegooijen, Alfvénic Turbulence in the Extended Solar Corona: Kinetic Effects and Proton Heating, *Astrophys. J.*, **594**, 573, 2003.

Y. Chen, R. Esser and Y. Q. Hu, Stagnation flow of O⁵⁺ ions in the source region of the slow solar wind at solar minimum, *Astrophysical J.*, accepted, 2003.

R. Esser, Ø. Lie-Svendsen, Y. Chen, and R. Edgar, Observational and theoretical constraints on the heating and acceleration of the fast solar wind, proceedings of the 10th Solar Wind Conference, M. Velli editor, in press, 2004.

O. Lie-Svendsen and R. Esser, Gyrotropic modeling of minor ions in the solar corona: Changes in abundances and temperatures with heating rate, in preparation.

M. Karovska, D. Dobrzycka, M. Marengo and R. Esser, High latitude coronal mass ejection, in preparation.

3. Invited Talks at Meetings

Ruth Esser, Minor Ions in the Solar Corona and Wind, UVCS Science Meeting, Maine, USA, 2000.

Steven R. Cranmer and Ruth Esser, Cyclotron Resonance of Ions in the Solar Corona: Observations and Models, IAGA-IASPEI Joint Scientific Assembly, Hanoi, Vietnam, 2001.

Ruth Esser, Observational and theoretical constraints on the heating/acceleration of the solar wind, Solar Wind 10, Pisa, Italy, 2002.

Ruth Esser, Solar wind Acceleration: Observations and Theory, International Symposium on Plasma Physics, Norway, 2002.

Ruth Esser, The Solar Atmospheres: Winds and Storms, Meeting of the Norwegian Physical Society, Sundvolden, Norway, 2003.

4. Invited Seminars

Ruth Esser, Minor ions in the solar wind, Turin Astronomical Observatory, Italy, 2001.

Ruth Esser, Differential ion flow speeds, Max-Planck Institute, Bonn, Germany, 2001.

Ruth Esser, Properties of the solar wind, Princeton Plasma Laboratory, USA, 2001.

Ruth Esser, Ion fractions in the solar wind, Institute for Theoretical Astrophysics, Oslo, Norway, 2002.

Ruth Esser, High speed wind from polar coronal holes, STELAB, University of Nagoya, Japan, 2002.

Selected Conference Presentations

Habbal, S. R.; Arnaud, J.; Johnson, J.; Hegwer, S.; Ene, A.; Hale, J.; Esser, R.; Arndt, M.; Kohl, J. L.; Daw, A.; Faurobert, M.; Woo, R.; Habbal, F.; Havasy, R.; Alford, J. N., Polarized Intensity Measurements of the Corona during the 21 June 2001 Total Solar Eclipse, American Geophysical Union, Fall Meeting 2001, abstract SH11C-0716, 2001.

Miralles, M. P.; Cranmer, S. R.; Esser, R.; Kohl, J. L., UVCS/SOHO Observations of Coronal Holes from Solar Minimum to Solar Maximum, American Geophysical Union, Fall Meeting 2001, abstract SH32A-0721, 2001.

R. Esser, O. Lie-Svendsen, Y. Chen, and R. Edgar, Constraints on coronal heating derived from modeling solar wind ion compositions, Solar Wind 10, Pisa, Italy, 2002.

Chen, Y., R. Esser, and Y. Hu, Formation of minor ion charge states in the fast solar wind: roles of differential flow speeds of ions of the same element, American Geophysical Union, Fall Meeting 2002, abstract SH12A-040, 2002.

Chen, Y.; Esser, R.; Hu, Y, MHD Modeling of the Halo Electrons in the Fast Solar Wind, American Astronomical Society, SPD meeting 34, 06.09, 2003.